U.S. Department of Transportation
Federal Aviation Administration

Aeromedical Research Resume
Research Project Description Subtask for FY99

(2) Title: Free Flight: Studies for the Integration of General Aviation	***2. Sponsoring Organization/Focal Point (FP)*** AAM-1; J. Jordan, M.D. AFS-400; R. Wright (FP) AND-710; P. Hwoschinsky (FP) AAR-100; M. Pettitt, Ph.D.	***3. Originator Name, Organization, Phone :AAM-510; 405-954-6826*** Kurt M. Joseph, M.S. AAM-510, (405) 954-9155
		4. Origination Date: January 1996
5. Parent RPD Number: Flight Deck Human Factors	***6. Subtask Number:*** AAM-A-98-HRR-514	***7. Completion Date:*** September 2000
8. Parent MNS: 187	***9. RPI Manager Name, Organization, Phone:*** David J. Schroeder, Ph.D. AAM-500, FAA Civil Aeromedical Institute (405) 954-6825	

10. Research Objective(s):

Identify and evaluate issues that concern the general aviation (GA) pilot and arise as a direct consequence of the change from the current NAS to the concepts associated with Free Flight (FF). In particular, identify those combinations of equipment, flight segment, traffic density and type of airspace that offer promising approaches to FF concept developments and those that do not. Specific circumstances and combinations of variables leading to success or failure of the criterion of maintaining separation assurance will be detailed and evaluated. Another objective of this research is to ensure that FF system concepts and variations tested are based on clearly defined NAS functional and performance requirements for a particular set of FF operations, rather than being influenced exclusively by technology that is available at a point in time, by air transport needs and preferences, or by political / organizational factors. A key issue in this research project is, “Can the separation assurance function (SAF) in a FF system be shared or shifted in real time between the pilot and controller, each supported by a particular level of automation within GA mission structures”.

11. Technical Summary:

The development of a functional architecture for traffic flow management (TFM) is an important step in the proposed technical approach. Here, human factors payoffs can be realized by identifying human performance measures (workload) and criteria for discriminating among candidate FF system concepts, and by evaluating those candidates through analytic and computer-based simulation studies. Accordingly, a GA FF system and function analysis will be conducted to identify the specific tasks and conditions that are performed in the following FF mission segments: (a) low-level en route; (b) transition from en route to terminal airspace; and (c) transition from terminal airspace to the airport traffic area (i.e., tower). These analytical data will be used to identify and specify information and display requirements and to develop experimental protocols for use in real-time simulation provided by a GA aircraft cockpit integrated with an ATC workstation. Fundamental to the technical approach used here is the acknowledged need to perform a “front-end” analysis that ensures understanding of NAS system implications and protects against “sub-optimization” of FF system design.

12. Resource Requirements:

	FY 98	FY 99	FY 00
FAA Staff Years	3.0	3.0	3.0

13. Description of Work:

(2) Brief Background

The National Airspace System (NAS) has been unable to keep pace with current demands and will continue to degrade as level of air traffic increases over the next several years. According to the report of the RTCA Select Committee on Free Flight, the NAS is plagued with insufficient capacity, limited access, and excessive operating restrictions that have escalated operating costs, increased delays, and generally decreased efficiency. FF is briefly defined as "A safe and efficient flight operating capability under IFR in which operators have the freedom to select their paths and speeds in real time." The major functional requirement that must be filled irrespective of FF approach is the assurance that aircraft separation be maintained at all times, or the "Separation Assurance Function" (SAF). Three events requiring control during FF operations involve (1) tactical [short-term] conflict resolution, (2) traffic flow management (TFM), and (3) entry into special use airspace (SUA). The primary difference between the current system and the FF concept is that, under certain conditions, GA pilots will be able to operate their flights without specific route, speed, or altitude clearances.

FF concepts will require redefinition of the roles, responsibilities, and authority of the pilots and controllers in maintaining aircraft separation under conditions of uncertainty. Roles and responsibilities are likely to be dynamic during flight, with shifts between primary system components. Successful operation of the FF system will depend upon the development of new rule-based procedures and guidelines that provide for smooth and timely transition depending upon existing operational conditions and circumstances. FF for GA crewmembers will lack the dispatcher or "company" component of the air transport system. This entity helps to perform flight planning and flight following functions. In the current system, flight service stations (FSS), transcribed weather, and pilot reports (PIREPS) help the GA pilot with those functions. System concepts for GA FF systems will need to recognize these functional requirements, particularly if the FSS are discontinued or become highly automated.

(*2) Statement of Work*

The technical approach proposed is guided by the systems engineering principle of establishing functional requirements and operating conditions as a prerequisite to developing and evaluating candidate system designs. This "front-end" analysis will produce various FF system concepts that can be simulated in conjunction with varying levels of automation, in the cockpit or on the ground, or both, and evaluated against criterion levels of performance. Other criteria will need to be addressed that involve the performance of airborne (e.g., pilot) and ground-based functions (e.g., ATC and TFM). For example, optimizing the surveillance function to meet a particular SAF requirement cannot be allowed to result in degraded performance of tasks related to other functions (e.g., navigation and communication). A general hypothesis is that procedures and equipment can be developed to allow GA aircraft to operate safely and effectively in a FF environment.

Task 1: Perform Human Factors Analysis of FF Operational Concepts. Use FAA Flight 2000 Operational Concept to identify and specify proposed technological devices, and the associated enhancements in functional capability that these devices will afford GA pilots. Much emphasis should be placed on the enhanced functional capability provided by use of digital data-link communication, augmented satellite navigation, and airborne surveillance technology. Technical information may need to be gathered from various sources, including avionics manufacturers, and, survey data may need to be gathered to determine the extent of GA pilot familiarity with technological concepts (e.g., using GPS as a primary means of navigation). Recent estimates indicate that approximately half of the GA aircraft in Alaska already have Global Positioning System (GPS) units, most of which are the hand-held type.

Enhanced functional capabilities should be described in a common framework that reveals their impact on GA pilot functions and tasks as they are performed in the context of Scenario 4 of the Flight 2000 Operational Concept. The framework should be designed such that it yields several important questions that can serve as input for Task 5. For example, how would GA pilots use the greater navigation precision afforded by GPS to achieve the prescribed limits that would be imposed by concepts such as Required Navigation Performance (RNP)? How would GA pilots use surveillance information that is derived from ADS-B to perform tasks such as station keeping within certain limits? How would GA pilots use data-linked flight information services to avoid risky flight conditions (e.g., weather, etc.)?

Task 2: Analyze FF Pilot-System Functional Relationships. Use the output from Task 1, along with bottom-up analytical techniques, to illustrate functional relationships between technological devices and GA pilot mission goals in the context of Scenario 4 of the Flight 2000 Operational Concept. Several functional relationships may exist for each of the questions posed in Task 1. For example, GA pilots may use several different equipage configurations to achieve similar navigation performance requirements for a particular environment. When this is the case, assessing the costs and benefits to performance of each configuration should identify the best functional relationship. Identification and specification of these relationships should be based on information provided by GA pilots, and will require appropriate use of methods (e.g., structured interviews, cognitive walkthroughs) for eliciting information. The survey data from Task 1 may be useful for establishing the breadth and depth of questions that should be asked during the information elicitation process.

A suitable framework should be utilized to map and illustrate functional relationships. Several frameworks exist, including Rasmussen's “means-end hierarchy”, which is consistent with a bottom-up analysis of functional relationships. Selection or development of a specific framework for illustrating functional relationships must be amenable to Task 3 protocol development. Formatting consideration also should be given to use of this information for functional interface design.

Task 3: Create Protocols and Conduct GA FF Simulation Study. Develop experimental protocols to test and evaluate, via real-time simulation, the various candidate approaches for fulfilling GA pilot functional and task requirements. Protocols used here would be devoted to defining the bounds of those independent variables that are highly deterministic of FF system outputs; that is, levels of traffic, weather, pilot proficiency, and so forth, which may combine to cause degradation in performance and loss of SAF. An important test of the variable allocation of SAF would be embedded within a research protocol that involves a shift to the aircraft and a return shift to ATC due to increased traffic density. Experimental protocols would probably assume some form of Cockpit Display of Traffic Information (CDTI) driven by traffic information that is sensed by ground-based surveillance radar and transmitted via data link.

The pseudo-vehicle feature of AGARS could be used to simulate other airborne traffic and the alternate pilot workstation could be incorporated to investigate decision making by a second pilot under conflict alert conditions.
Also, data-link research concerning candidate CDTI design options might be conducted as part of this study. The products of this study would involve preliminary task-based data on pilot ability to perform the primary functions of navigation, communication, and aircraft separation under a limited set of flight and traffic density conditions. A primary dependent variable (as noted above) would be degradation in the SAF function as measured by the number of interventions required by ATC due to conflict alerts. Also of interest would be the number of information transfer events between aircraft and ATC. Although there would be fewer control communications, there may be more advisory communications. This could be a bilateral issue in which the pilot and ATC necessarily both engaged in the "Be Advised" communication form.

Task 4: Conduct Follow-on Studies. Design of follow-on studies should be responsive to needs for testing additional concepts, configurations, alternatives and variations in surrounding operational environments. The resulting data will provide a basis for development of FF design guidelines for hardware, software, and procedures for cockpit systems that were to be emphasized. Although the focus of this project is on aircraft design, considerable useful data will be obtained on ATC functions under the conditions simulated. The degree to which ATC issues are considered will depend upon the extent to which high fidelity, ATC simulation can be conducted jointly and in real time with cockpit simulation.

Task 5: Identify Common Information Requirements of GA Pilots and Air Traffic Service Personnel for Use in Decision Support System Development. Interdependencies (via communication links) in flight planning and flight execution between pilots and air traffic service providers (i.e., ATC, FSS) will be described and analyzed with respect to common information access and decision making requirements. This functional description will be contextually anchored to a typical GA IMC flight scenario. Candidate scenarios are available for AAL, ASW, and ANM Regions. The framework for functional descriptors will be such that the impact of emerging technological resources for Decision Support Systems (DSS) and Collaborative Decision Making (CDM) can be defined. Because the goal is to provide pilots and air traffic service providers with access to the same information for decision making in flight planning and execution, task-analytic techniques will be used to determine interdependencies and achieve a description that can be used to develop team-centered procedures.

Methods described in Sage and those in Wickens will be relied upon extensively for completion of this task. While Wickens et al. (1998) is generally "ATC-centered," this task will produce several team-centered concepts for a DSS, all of which foster collaboration among pilots and controllers relative to potential role and responsibility changes associated with evolving technology-driven Free Flight concepts. The concepts for a DSS will be compared to those of avionics vendors to the extent that the software contained in the latter can be modified to achieve team-centered DSS criteria. These concepts will be provided in the form of display/control specifications for an interface that can be evaluated using AGARS human-in-the-loop simulations.

Task 6: Report Findings and Recommendations. This task involves the periodic and continuing effort of organizing findings to address priority questions and issues and providing recommendations as to design approaches, conditions, configurations, and policies that tend to optimize the human role in FF systems, from both cockpit and ATC viewpoints.

14. Intended End Products/Deliverables:

End products produced will include (1) information and task requirements data for various mission profiles; (2) software developments and protocols for real-time simulation of alternative FF system concepts; (3) objective performance data reflecting pilot (and controller) performance as a function of a specified scenario; (4) various sets of recommendations concerning pilot proficiency and training, cockpit design and layout, and operating procedures with respect to specific FF system alternatives; and (5) recommendations for future directions in FF design including perceived requirements for futu technological advancements in airborne and surface capability, pilot training, and system designs, as well as for further simulation research.

15. Schedule/Milestones:

Task 1: Perform Human Factors Analysis of FF Operational Concepts	Completed
Task 2: Analyze FF Pilot-System Functional Relationships	Completed
Task 3: Create Protocols and Conduct GA FF Simulation Study	99Q1
Task 4: Conduct Follow-On Studies	99Q3
Task 5: Identify Common Information Requirements of GA Pilots and Air Traffic Service Personnel for Use in Decision Support System Development	99Q4
Task 6: Report Findings and Recommendations	00Q4

16. Procurement Strategy/Acquisition Approach/Technology Transfer:

This project will be supported by a contractual effort, particularly in the performance of Task 5 to obtain functional requirements data. Other contracts may be awarded during FY99 to deal with specialized issues or questions such as the development of decision aiding tools, design of specific displays, identification of training requirements, and so forth. Guidance has been obtained from meetings and documentation produced by RTCA, Inc. and the SAE G-10W Subcommittee on Free Flight. Technology transfer will likely occur through such avenues as Integrated Product Teams (IPTs), joint FAA/industry working groups, specialized issue groups, and through the preparation and promulgation of requirements and guideline documents providing human factors specifications, standards, and procedures for the various FF conceptual developments tested.

17. Justification/History:

The notion of FF within the NAS presents a number of critical human factors issues and problems, as have been noted and discussed in previous sections of this ARR. This is particularly true when considering GA in such an environment. GA missions and circumstances must be considered in a timely fashion, along with issues that attach to the air transport community, if GA is to make use of savings and improvements in national air transport that are promised by FF. Basically, this concerns the need to identify the various forms of information required, manner of presentation, and use in aviating, communicating, and navigating and surveillance. This project recognizes the need to include GA requirements in FF system design and presents a systematic plan for their consideration in real-time simulation research.

18. Issues:

The salient questions associated with the concept of FF are where and under what conditions should the responsibility for separation assurance be assigned? Should it be ground based, aircraft based, or a joint responsibility shared by ATC and the Pilot? This research proposal assumes that the SAF will not be assigned as the sole responsibility of any one entity. Rather the SAF is likely to be shared between ground and air, depending upon circumstances and/or limitations of GA missions, which are the subject of this research project. A further issue in the development of a FF capability is the degree to which there is an integrated human factors structure. A systematic and structured approach to integrating human factors considerations in the extra-agency developments related to FF as well as in the internal technical implementation of FF operational concepts is imperative. Expert human factors involvement at every stage of FF development is needed to identify and resolve the basic human interface requirements that attach to any one conceptual approach and to transitions among concepts during FF operation. General support must be forthcoming that supports human-centered, performance-based analyses and human in-the-loop engineering and simulation.

Since this research involves the use of human participants serving as pilots and ATCS's in the CAMI flight simulation facility, research protocols will be submitted for review and approval by the CAMI Institutional Review Board (IRB) to ensure that proper consideration and protection is afforded the human participants.

19. Transition Strategy:

A joint industry/FAA steering group will undoubtedly guide the strategy for transitioning FF developments into the NAS on a cautious, evolutionary basis. The ongoing Advanced General Aviation Transport Experiments (AGATE) program and associated FF objective will provide a highly lucrative transition customer. FF concept test areas are likely to be established in low-density traffic areas, which may include representations of enroute, terminal and tower control entities. These may not be actual facilities but simulated ones located at specified geographical points for purposes of system and operational testing of various FF system concepts. It is also likely that regulatory action will be required, at least on a temporary basis, to facilitate efforts to transition FF concepts to the operational domain.

20. Impact of Funding Deferral:

The human factors implications and potential impact of the various FF concepts on the GA pilot and the air traffic controller are critical to the test and evaluation of those concepts, and to the process of implementing them operationally. Continued development of FF without commensurate investments in closely coordinated human factors engineering (HFE) design, development, and test efforts related to GA circumstances and requirements can be expected to result in sub-optimized FF system performance at the very best varying to major decrements in performance of the NAS including impaired system effectiveness, increased risk and compromised safety. Deferred funding of carefully conceived, planned and executed HFE support could easily result in the complete failure of the FF system concept.

21. R&D Teaming Arrangements:

Coordination will be maintained with other agencies and activities currently involved in conducting FF human factors research such as the SAE G-10W Subcommittee on Free Flight, FAA William J. Hughes Technical Center, NASA, MITRE, and the National Research Laboratory in the Netherlands. The possibility of teaming with another agency, industry or university group has been pursued, and will be used to align current efforts with the NAS Modernization

Action Plan. The AGATE program also presents several opportunities for coordinating or teaming with industry partners in the development of flight systems and pilot training requirements, which would facilitate the development and test of innovative GA aircraft systems.

22. Special Facility Requirements:

CAMI's GA Flight Simulation Facility will be required for this study. Depending upon the level of technology to be represented in the cockpit, either the BGARS or AGARS flight simulator will be available. AGARS provides for rapid prototyping of cockpit displays to represent highly innovative multi-function displays. Furthermore, AGARS incorporates an on-line ATC workstation that will be employed.

23. Approvals (Signature Authority):

	Project Revalidation	***Performing Organization***
______________________ Director, Flight Standards Service (AFS-1)	______________ Date	________________ William E. Collins, Ph.D. Director, FAA Civil Aeromedical Institute, AAM-3
______________________ Jon L. Jordan, M.D. Federal Air Surgeon, AAM-1	______________ Date	______________ Date